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TECHNICAL REPORT RS-81-7

AN EVALUATION OF PARTICLE IMPACT NOISE DETECTION (PIND) TESTING

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August 1981

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TR-RS-81-7	2. GOVT ACCESSION NO. AD-A111 347	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Evaluation of Particle Impact Noise Detection (PIND) Testing		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dr. David Kerns MAJ Dicky Love Dr. Victor Ruwe		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Commander, US Army Missile Command Attn: DRSMI-RS Redstone Arsenal, Alabama 35898		12. REPORT DATE August 1981 13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Commander, US Army Missile Command Attn: DRSMI-RS Redstone Arsenal, Alabama 35898		15. SECURITY CLASS. (of this report) Unclassfied 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Loose particles
Device cavity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this report scientific evidence is presented that PIND testing, in its present format, is not an effective screening tool for particle contamination in microelectronic packages.

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I. INTRODUCTION

PIND testing - Particle Impact Noise Detection Test - is a technique for detecting the presence of loose particles in a cavity. It has been used for many years, one of the earlier applications being detection of particles in electromechanical relay packages. More recently it has been applied to integrated circuit packages and a military standard written to describe the test. The PIND test, in the format which we now know it, had its beginning with the catastrophic failure of a Delta launch vehicle which was traced to a component failure resulting from a bit of loose wire. NASA then contracted with a number of companies to develop nondestructive techniques to detect this failure mechanism. PIND grew out of this effort. The contributors to this effort are many and are referenced in the bibliography.

MIL-STD-883, Method 2020 describes the purpose of the PIND test: "The purpose of this test is to detect loose particles inside a device cavity. The test provides a nondestructive means of identifying those devices containing particles of sufficient mass that, upon impact with the case, excite the transducer. Because of the limited efficiency of this test method, it may be desirable to subject devices to several sequences of this test in order to achieve desired confidence."

The PIND test, although well intended, remains controversal in the industry in regard to its value and the level of confidence that one can place in this test. This report will summarize the key studies that have been done on PIND as well as describe the practical experience of users of the PIND test. These results will be summarized, with the goal of providing insight into the present status of PIND in the industry, its value in detecting particle contamination in microcircuits, and the projected future use of PIND testing.

In this report direct quotations are taken from some of the referenced literature in describing the relevant experiments. The origin of such quotations should be clear from the reference or the context.

II. PRINCIPLES OF PIND TESTING

The basic mechanism by which PIND testing operates is the detection of acoustic energy which is produced when loose particles strike the interior of a package being shaken. A cavity within a microelectronic component can contain small conductive particles as a result of incomplete cleaning or general processing. These particles can cause a malfunction or catastrophic failure of the circuit if an unwanted electrical path is produced; thus detection of such particles is desirable.

The detection of the particles is accomplished by the use of a test setup as shown in Figure 1. The major elements of the testing equipment are as indicated. The devise under test (DUT) is fixtured so as to be held firmly i place on the shaker. The DUT is coupled to a transducer which detects the acoustical energy generated. The vibration or noise generated due to loose interconnections or fixturing will produce signals in addition to that produc by loose particles within the package. The energy spectrum can extend to fre quencies well above the audio frequency range. The signal generated at the transducer is amplified by the ultrasonic amplifier as indicated in the figure. A filter is also used to remove the 100 to 30 kilohertz shaker frequency and background noises from the transducer output. The signal from the amplifier is interfaced to visual and audio monitors to provide data to the operator. A threshold detector is used to provide a postive signal when the output from the amplifier exceeds a preset threshold. A sine generator is used to set the amplitude and frequency of the shaker motion.

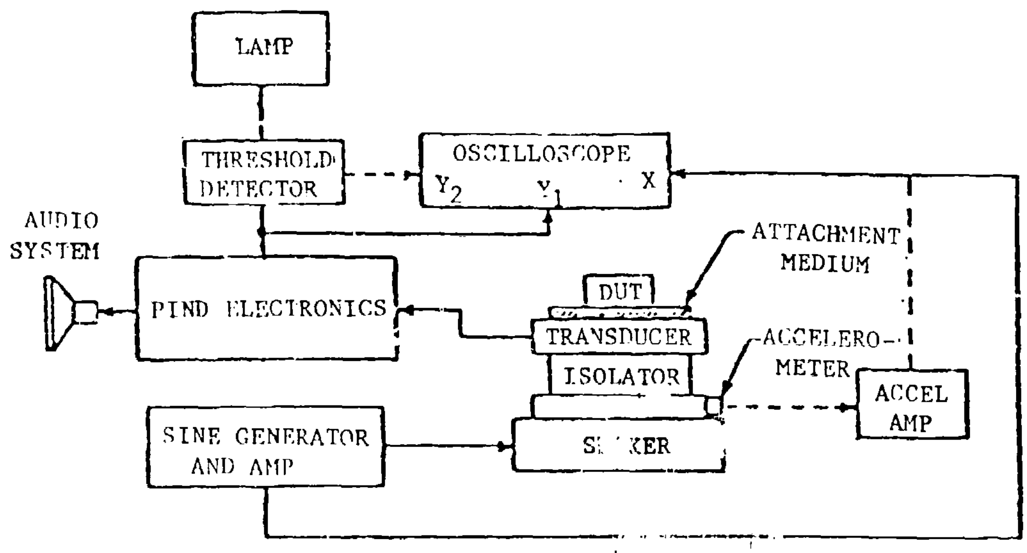

Figure 1. Typical particle impact noise detection system.

The test method 2020.1 is included as an appendix to this report. The purpose of the test method is:

> "1. PURPOSE. The purpose of this test is to detect loose particles inside a device cavity. This test provides a nondestructive means of identifying those devices containing particles of sufficient mass that, upon impact with the case, excite the transducer. Because of the limited efficiency of the test method, it may be desirable to subject devices to several sequences of this test in order to achieve desired confidence."

The test method requires a test sequence of:

"3.3 Test Sequence

a. Pre-test shock

b. Vibration 3-5 seconds

c. Co-test shock

d. Vibration 3-5 seconds

e. Co-test shock

f. Vibration 3-5 seconds

g. Co-test shock

h. Vibration 3-5 seconds

i. Test for acceptance"

The main feature of this test sequence is the application of a co-test shock to produce sufficient energy to dislodge particles within the cavity. This shock is produced by a copper rod brought to momentary contact with the vibrating DUT.

The rejection of devices is determined by the detection of noise bursts above the background noise either by audio indication, visual indication on a scope or exceeding a threshold detector limit. The details of the method are contained in Appendix I.

III. RESULTS OF INDUSTRY EXPERIENCE AND STUDIES

A. National Bureau of Standards (NBS) Study

In an exhaustive study performed in 1978 by the National Bureau of Standards (NBS) for NASA, an attempt was made to work exclusively with controlled samples. Using deliberately "seeded" packages and totally particle-free packages as controls, several hundred packages were examined. Variables included: a) Particle size and shape b) Presence/absence/magnitude of co-shock c) Acceleration of shaking d) Package type and e) Four different PIND machine manufacturers or configurations. NBS has an excellent reputation for implementing controlled experiments and this 62-page detailed report is no exception. Yet, analyzing known conditons, they detect particles in deliberately contaminated packages with only 40 to 60% success and, conversely, detected "particles" in the known clean samples in 10-20% of the packages.

Some direct quotes from the Executive Summary of this report:

> "The work described constitutes an evaluation of the test procedures and apparatus specified in MIL-STD-883, Test Method 2020, Particle Impact Noise Detection Test."
>
> "The intent of the work was not to provide in any sense a definitive study of PIND procedures, nor was it to devise an exceptionally ingenious method that would solve the "the" PIND problem. As an index to the state of knowledge in the PIND area, consider the following: It has been estimated that a thorough examination of one aspect of PIND--the role of electrostatic mechanisms in the immobilization and release of particles--would require over five man years to achieve basic understanding with no guarantee of any information being developed that could be used directly in PIND testing (although it is likely that information that could be used by microelectronic device designers would be generated)."

It would appear that NBS is suggesting there is a fundamental measurement problem with this technique. Continuing to quote from this NBS report:

> "These second-stage tests were carried out on 252 specimen devices, representing six package types and a number of different seed particle sizes in several materials (see Table I for detailed list); these devices were characterized by the commercial supplier as either intentionally seeded with a single particle or free from any particle that could result in detection in a PIND run. (It should be noted that particles such as aluminum sphere 0.025 mm in diameter have a low enough mass -- nominally 0.02 pg -- that the supplier, in common with other test operators, did not regard Test Method 2020 procedures as adequate for their detection, even if free.) These seeded and unseeded specimens were the subject of seven trials in the NBS laboratory and, later, of three additional trials in the supplier's facility (Appendix I constitutes detailed information on the results from each trail; summaries are presented in Table II for NBS and Table III for the supplier.)"

"After several of the NBS trials were completed, it became obvious that according to the supplier's characterization (seeded or unseeded) the NBS results were showing low detection scores for seeded specimens and, even less understandably, detections in unseeded ones. There were a number of possible explanations; these are examined in detail in 2.1.4. Although it was not possible to arrive at a definitive explanation of the anomalies, it is likely that some event affected the specimens between the time they were tested prior to shipment to NBS by the supplier and the time of the first NBS trial. It is noteworthy that the three post-NBS trials conducted by the supplier (at his suggestion, in an attempt to resolve uncertainties) are in better agreement with the NBS results that with is initial characterization."

This further illustrates that PIND test reproducibility is poor. NBS also said.

"The chief recommendation applying to the development of the Test Method, given in 4.1, is that semi-automatic apparatus be used to avoid difficulties with operator fatigue, judged to be severe in a production line testing operation. It should be pointed out, however, that the NBS results, even when corrected as suggested in 3.1, do not show high detecability scores even for the special particles used as seeds, which may not be (indeed probably are not) typical of the free particles enclosed in sealed microelectronic devices on the production line. As device geometries grow smaller, the size of an "acceptable" conducting particle will drop, yet there is no guarantee that the mechanisms producing particles will compensate by generating small particles, although if this were the case, present-day PIND procedures would not be likely to detect them. The point is simply that the PIND art is an uncertain one; the relatively limited NBS trials (compared to operators who have tested tens of thousands of devices) can perhaps best serve to provide a caution related to overreliance on PIND as a method of qualification."

The fact that the National Bureau of Standards has to refer to PIND testing to the MIL-SPEC method as an "uncertain" "art" based on their own detailed analysis is one of the most significant of the numerous indictments of the technique.

Following are the data tables referenced in the above NBS comments, illustrating the inconsistencies in the method.

TABLE I.

GROUP I SPECIMENS

NUMBER OF SPECIMENS	PACKAGE TYPE	PARTICLE CHARACTERIZATION				
		MATERIAL	SHAPE	NOMINAL DIAMETER (mm)	NOMINAL DIAMETER (in)	CALCULATED NOMINAL MASS (μg)
2	TO-5	Gold	Sphere	0.102	0.004	10.6
2	TO-5	Gold	Sphere	0.051	0.002	1.3
2	TO-5	Lead	Sphere	0.152	0.006	21.1
2	TO-5	Lead	Sphere	0.076	0.003	2.6
2	TO-5	Lead	Sphere	0.025	0.001	.1
1	TO-5	Unseeded				
2	TO-18	Gold	Sphere	0.102	0.004	10.6
2	TO-18	Gold	Sphere	0.051	0.002	1.3
2	TO-18	Lead	Sphere	0.152	0.006	21.1
2	TO-18	Lead	Sphere	0.076	0.003	2.6
2	TO-18	Lead	Sphere	0.025	0.001	.1
1	TO-18	Unseeded				
1	[a]Flatpack	Gold	Sphere	0.051	0.002	1.3
1	Flatpack	Gold	Sphere	0.102	0.004	10.6
1	Flatpack	Lead	Sphere	0.076	0.003	2.6

[a] With metal lid, 6.4 x 3.3 mm (0.25 x 0.13 in), 14 lead

TABLE II.

SUMMARY OF SEVEN PIND TRAILS CONDUCTED BY NBS ON GROUP II SPECIMENS

Trial No.	Shaker Used	Pre-Test Shock	Co-Shock[a]	Detection System	Test Fre-quency (Hz)	Accleration Level g_n	Detection Score[b] for 198 Seeded Specimens (%)	Detection Score[b] for 54 Unseeded Specimens (%)
1	NBS	Apparatus C	System B	System B	60	±10	48	24
2	NBS	Apparatus C	System B	System B	43-96[c]	±10	50	24
3	NBS	Apparatus C	System B	System B	43-96[c]	±20	55	26
4	NBS	Apparatus C	System B (applied every 10 Hz)	System B	sweep from 250-40	±10	45	22
5	System A	Apparatus C	Manual w/ copper rod	System A	60	±10	39	17
6	NBS	Apparatus C	System B	System B	60	±10	43	22
7	System A	Manual table tap	Manual w/ copper rod	System A	60	±10	38	15

[a] A maximum of three co-shocks was applied during each run, except in the case of swept-frequency trials.

[b] The detection score, in percent, is defined as 100 times the quotient of the number of specimens in which a particle was detected and the number of specimens tested.

[c] The frequency used within this range for a given package type was determined in accordance with the Test Method.

TABLE III.

SUMMARY OF THREE PIND TRIALS CONDUCTED BY SUPPLIER ON GROUP II SPECIMENS FOLLOWING NBS TRAILS 1 THRU 7[1]

Trial No.	Shaker Used	Pre-Test Shock	Co-Shock	Detection System	Test Frequency (Hz)	Acceleration Level g_n	Detection Score for 198 Seeded Specimens (%)	Detection Score for 54 Unseeded Specimens (%)
8	System A	manual table tap	manual with copper rod	System A	60	$\pm$ 10	40	11
9	System D	System D, 1500 g_n	System D, 1000 g_n	System D	60	$\pm$ 10	32	0
10	System D	System D, 1500 g_n	System D, 1000 g_n	System D	in accordance with data in Method 2020	$\pm$ 20	34	2

1 System D refers to a newly available semi-automatic system incorporating means for imparting pre-test shock and co-shock accelerations to the specimen.

B. Adolphsen/NASA Goddard Space Flight Center Study

A most recent and complete study of the validity of PIND testing was performed by John Adolphsen of NASA Goddard. He performed a large round-robin experiment to determine the sensitivity of detection of particles not permanently attached and to see how they depend upon a number of variables such as particles size, shape and composition, package style, test method, attachment method, or test equipment. To assure positive knowledge of the true detection capability of testers, particles of different materials and sizes were seeded into a variety of package styles, while other packages were left unseeded. About one hundred aerospace companies, including users, test labs, and semiconductor manufacturers, then agreed to participate in a round-robin program to PIND test these devices and demonstrate the effectivity of this means of particle detection at the operational level. The goals for the program were: (1) to test the effectiveness of PIND on a broad base of testers, users, test labs and semiconductor manfacturers to determine what variability exists in the industry as a whole; (2) test the MIL-STD test method itself, by determining if operational problems or deficiencies exist in the requirements, apparatus, or procedures and to determine if one of the two variations of the test is superior to the other; (3) suggest modifications to the test method, if so included, based on round-robin results; (4) provide information on the effects of several variables, such as: package style, particle size, size and shape, operator experience, test equipment, acceleration levels, and shaker operating frequency: (5) provide information to testing groups on their ability to detect particles, both absolutely and relative to the capability of others, (6) decrease the subjectivity of statements made regarding PIND effectiveness; (7) provide information to potential buyers of PIND testing and their advisors regarding the effectiveness and cost effectiveness of PIND testing.

It was decided to split 297 pieces into three equal groups for concurrent testing. Each testing company was asked to test their sample group of 99 pieces in at least two ways, i.e., strictly in accordance with conditions "A" and with condition "B" of test method 2020.

In addition, if they normally did not test in accordance with method 2020, they were asked to do it in their third way, also. If a company wanted to test in any single way more then once, they were invited to do so, but were asked to retest the whole group, not just those survivors to the previous tests. The range of package styles included six monolithic and five hybrid styles. The composition of the seeding material included gold, aluminum, lead or silicon-aluminum. The seeded material varied in size and shape and also with the size of the package. Another variant employed was the method which was used to attach the device under test to the equipment. Water soluble jelly, alcohol jelly, or double sided sticky tape.

Several workers have suggested that there may be a "memory" effect which a device acquires with repeated testing. This memory effect acts to decrease the detectability of a particle in a package. If this effect exists, it might adversely influence the scoring of those companies at the end of the round-robin. If the effect is sufficiently large, is should be obvious by plotting company results in chronological order of testing.

Although the round-robin is not yet complete, and some data are sparse, or not yet computer formatted and analyzed, some conclusions can be drawn at this time. Adjustment of scores, after accurately determining if particles are present in packages, many modify some scores, but changes are not expected to be major.

1) The most obvious conclusion is that PIND testing may be better or worse than some expected to be demonstrated, <u>but it is not as good a screen test as most other MIL type screens</u>. Average detection scores in the low or mid 40's for PIND testing compare poorly with scores in the 90's for many MIL screens.

2) The range in detection scores from company to company is disturbingly wide. The implications of blind selection of a company to perform PIND testing may assume an unacceptably high risk. Alternatively, extensive training and qualification of testing companies may be necessary.

3) Detection sensitivity is highly package style dependent, and is the lowest for ceramic body packages.

4) As intuitively expected, detection capability increases with particle size.

5) For the different material seeded here, detection sensitivity does not appear to vary significantly.

6) Testing using condition "A" of test method 2020 appears to be superior to other methods, but further data and in-depth analyses are necessary before recommending its use in all cases.

7) Although no data were presented to support this conclusion, the differences in detection sensitivity between couplants is minor.

Aldophsen then recommended that companies which exhibit poor detection scores should emphasize training and motivation with their personnel who perform these tests. He also recommended that potential testers should be tested and qualified to perform PIND testing prior to imposition of PIND testing and award of contracts. He also recommended the use of seeded packages to be used as calibration standards. And finally he concluded with a recommendation that PIND testing should be used in programs where criticality of missions was high.

In further discussions with Mr. Adolphsen he has mentioned that his study showed there is about 3 to 4 superiority for conditions "A" testing over condition "B" testing. Another interesting aspect from a later discussion with Mr. Adolphsen was that of the companies who scored high on detection, which means that for packages which were seeded, they found many of them to show positive presence of particles, those same companies also scored high on the seeded. In other words, from the manufacturer's standpoint, he would be throwing away good devices.

Further tests by John Adolphsen have observed and substantiated the memory effect which was first mentioned by John Slocum at McDonnell-Douglas. As a result of corrections due to the memory effect mentioned, John Adolphsen feels that the score or the detectibility for PIND testing should be corrected to the vicinity of 44% rather than the previously mentioned 30%; however, this is still a disturbingly low detectibility figure.

C. Teledyne Study

The Teledyne Study was much more critical of the entire test method. In this study 60 hybrids were fabricated. Thirty were in smaller flat packs and the other 30 were in larger flat packs. The packages were seeded with three sizes of silicon particles and three sizes of lead-tin solder particles. The silicon particles and the solder particles ranged from 0.001 inch to 0.020 inch. Each part was tested three times and the results are tabulated in Table IV. as shown below. The conclusions that Dr. David comes to are summarized in the following tabulations:

1. The escape rate for conductive particles was 40%;

2. The escape rate for non-conductive particles was 2%;

3. The false alarm rate ranged from 5 to 10%;

4. The correlation coefficient was 0.6.

A further problem arose as a result of the testing in terms of induced damage at a rate of 10%. Dr. David questions the value of the entire test and claims it to be marginal at best. He further states that the test is most successful in detecting non-conducting particles which are typically not of interest in the hybrid circuit field. He further insists that with the high false alarm rate, sample testing with lot jeopardy is merely a form of Russian roulette. Testing until less than 1% of units fail is Russian roulette played an infinite number of times; it is very difficult to win that game. He also points out the added problems of increased cost and extended schedule along with the concomitant frustration.

David then concluded with the recommendations that:

1. The use of co-shock devices built into the shaker assembly rather than a copper rod or dental tool, would reduce the amount of induced damage.

2. The use of a threshold detector set at a high level far above the system noise level would serve to reduce the excess number of false alarms.

3. Repeated PIND testing would reduce the escape rate.

4. He recommends the use of coating the internal surfaces of hybrid circuits with a dielectric material to give positive protection against shorts caused by conductive particles.

TABLE IV. PIND Test Results

Package/Particle Type/Category	Escape Rate Test 1	Escape Rate Test 2	Escape Rate Test 3	Correlation Coefficient 1 to 2	Correlation Coefficient 2 to 3
SFP .001"Si	60%	100%	100%	0.2	1.0
SFP .005Si	40%	40%	60%	1.0	0.6
SFP .020"Si	0%	20%	40%	0.6	0.6
SFP .001"PbSn	100%	100%	100%	1.0	1.0
SFP .005"PbSn	100%	75%	0%	0.5	-0.5
SFP .020"PbSn	20%	40%	40%	-0.2	1.0
LFP .001"Si	60%	40%	60%	-0.2	0.6
LFP .005"Si	0%	0%	0%	1.0	1.0
LFP .020"Si	25%	25%	0%	1.0	0.5
LFP .001"PbSn	60%	60%	40%	0.2	-0.2
LPF .005"PbSn	0%	20%	20%	0.6	1.0
LPF .020"PbSn	0%	0%	0%	1.0	1.0
Combined	3%	44%	40%	0.54	0.65

SFP = Small Flat Pack

LFP = Large Flat Pack

IV. SUMMARY AND RECOMMENDATIONS

It is clear, statistically, practically, and demonstrably, that the present PIND technique is ineffective and even potentially detrimental in application to the particle problem. Unfortunately, in the rush to provide particle-free packages into high-rel applications, it is now obvious by many unbiased studies, that the PIND method might confirm the presence of particles no better than about 50% of the time and will cause rejection of particle free components up to 25%; in addition, it may be inducing some damage in the circuit. With the probability of successful event-prediction in the range of 50%, the test should not be utilized.

Elimination of the test has more advantages than its application: we would a) not falsely detect and reject 10-25% of the good devices b) not create devices with particles where there were previously none and c) not have gone through the cost, expense, and time lost for a PIND test.

It has been shown that in its present format the PIND test is a largely subjective test, with wide variations in results from one test system to another, and with unacceptable escape rates and false alarm rates for a MIL-SPEC. These rates were confirmed in several independent investigations in a rigorous manner by well-respected technical organizations. The test equipment and procedures need further improvements and refinements to obtain reproducible results. The following steps are recommended to alleviate the present serious problem:

1) Stop using PIND testing, except possibly for extremely high reliability requirements such as satellites. Recognize it is ineffective, as a general MIL-SPEC, potentially even contributing to the problem. Suspend the MIL-STD method 2020.1 indefinitely.

2) Enforce cleanliness in the pre-seal areas of assembly operations. The source of most conductive particles is known, as is the processes and process controls to eliminate them.

3) Apply a rigorous cleaning step just prior to the sealing operation. Such cleaning processes are well known and practical.

4) Require that <u>all</u> solid state devices with closely spaced conductor runs be covered with an insulated layer.

5) Require that no shallow angle bonding be allowed.

6) Continue to investigate improved methods of particle detection.

If these items are implemented, the ultimate reliability of all electronic components as regards particulate contamination will be considerably improved, and the utilization of the proven unacceptable PIND test will be unnecessary.

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APPENDIX I.
METHOD 2020.1

METHOD 2020.1

PARTICLE IMPACT NOISE DETECTION TEST

1. PURPOSE. The purpose of this test is to detect loose partic[illegible]s inside a device cavity. The test provides a nondestructive means of identi[illegible] those devices containing particles of sufficient mass that, upon impact with the [illegible]. excite the transducer. Because of the limited efficiency of this test method, [illegible]ay be desirable to subject devices to several sequences of this test in o[illegible] to achieve desired confidence.

2. APPARATUS. The equipment required for the particle impact noise detection (PIND) test shall consist of the following (or equivalent):

a. A dual beam oscilloscope capable of 500 kHz response minimum, and a sensitivity of 20 mV/cm for visual display of the particle noise and of the threshold detector. Alternatively, a single beam oscilloscope may be used in conjunction with a lamp indicator for the threshold detection circuit.

b. A threshold detector to detect particle noise voltage exceeding a preset threshold of 5 ±1 millivolt peak above system peak noise. See figure 2020-4 for an acceptable circuit to perform the threshold detection function.

c. An audio system with speaker to monitor the audio signal from the PIND electronics. If headphones are used, the system shall provide safeguards against loud noise bursts.

d. A vibration shaker and driver assembly with a payload consisting of the DUT, (PIND) transducer, the transducer isolator, preamplifier (when included), co-test shock mechanism (when included), a portion of the transducer cable and its restraints, capable of providing essentially sinusoidal motion at:
   1. Condition A - 20g peak at 40 to 250 Hz.
   2. Condition B - 10g peak at 60 Hz.

e. PIND transducer, calibrated to a peak sensitivity of -7[illegible].5 ±3 dB re one volt per microbar at a point within the frequency of 150 to 160 kHz.

f. A sensitivity test unit (STU) (see figure 2020-3) for periodic assessment of the PIND system performance. The STU shall consist of a transducer with the same tolerances as the PIND transducer and a circuit to excite the transducer with a 250 microvolt ±20 percent pulse. The STU shall produce a pulse of about 20 mV peak on the oscilloscope when the transducer is coupled to the PIND transducer with attachment medium.

g. PIND electronics, consisting of an amplifier with a gain of +60 ±2 dB centered at the frequency of peak sensitivity of the PIND transducer to amplify the transducer signal to a usable level for threshold detection, audio detection and oscilloscope display. The noise at the output of the amplifier shall not exceed 10 mV peak.

h. Attachment medium. The attachment medium used to attach the DUT to the PIND transducer shall be either a viscous acoustic couplant such as Automation Industries No. 50A4084 (or equivalent) or double-faced tape such as Permacel P50 (or equivalent).

i. Co-test shock mechanism or tool, consisting of the integral co-test shock mechanism of 2.d. above (when included), or a six-inch solid AWG No. 10 copper rod with rounded end, or other mechanism capable of imparting shock pulses between 200 and 1500g to the DUT. The duration of the main shock shall not exceed 100 microseconds.

j. Special mounting adapters for devices which have irregular surfaces (see 3.3.2).

k. Isolator material between the PIND transducer and the vibration shaker and driver when required to reduce background noise. The isolator shall have no resonance within the test frequency range.

1. A pre-test shock fixture capable of imparting shock pulses between 500 and 1800g to the DUT. The duration of the main shock shall not exceed 100 microseconds. A co-test shock mechanism integral to the shaker and driver may be used for this purpose.

3. PROCEDURES.

3.1 Test equipment set-up. The test equipment shall be connected as indicated in figure 2020-1 and set-up in a low background noise area. Critical settings to provide proper detection sensitivity, unless otherwise specified, are as follows:

a. Audio output volume shall be adjusted to a comfortable noise level output.
b. Shaker drive frequency shall be adjusted in accordance with figure 2020-2 for condition A, or at 60 Hz for condition B.
c. Shaker drive amplitude shall be 20g (condition A) or 10g (condition B) with DUT and mounting adapter (if any) in place.
d. Oscilloscope vertical deflection primary beam sensitivity (displaying PIND electronics output) shall be 20 millivolts/centimeter. Secondary beam sensitivity (if displaying threshold detector output) shall produce approximately a 2 centimeter deflection difference between the two states of the threshold detector. The secondary beam display (without horizontal deflection) shall be centered vertically and approximately 1 centimeter to the left or right of the primary beam display.
e. Oscilloscope horizontal deflection shall be adjusted to 4 cm and shall obtain drive from the sine generator/amplifier, amplified accelerometer, or a time base (2 ms/cm) triggered from the accelerometer output.

3.2 Test equipment checkout. The test equipment checkout shall be performed to assure proper system operation, when any of the following occurs:

a. After a change of vibration frequency.
b. System shut-down for any reason.
c. Change of operators.
d. Work shift change.
e. Prior to and after testing group(s) of devices or every 4 hours during the test operating period, whichever comes first. System deficiencies shall be corrected prior to test. Failure of the system to meet checkout requirements shall require retest of all devices tested subsequent to the last successful system checkout.

3.2.1 Shaker drive system checkout. The drive system shall achieve the shaker frequency specified in 3.1 b. and the shaker amplitude specified in 3.1 c. If a visual displacement monitor is affixed to the transducer, it may be used for amplitudes between 0.04 and 0.12 inch (1.02 and 3.05 mm). An accelerometer may be used over the entire range of amplitudes and shall be used below amplitudes of 0.040 inch (1.02 mm).

3.2.2 Detection system checkout. With the shaker deenergized, the STU transducer shall be mounted face-to-face and coaxial with the PIND transducer using the recommended attachment medium. The STU shall be activated several times to verify low level signal pulse visual and threshold detection on the oscilloscope (approximately 20 millivolt peak or 10 millivolt peak above system noise).

NOTE: Not every application of the STU will produce the required amplitude but the majority of applications will do so.

3.2.3 System noise verification. For proper system operation, no extraneous noise can be permitted to exist in the system. During proper operation, the normal system noise, as observed on the oscilloscope, will appear as a fairly constant band and must not exceed 10 millivolts zero to peak. Extraneous noise is defined as noise in the system other than the permissible background noise that is present with no device on the transducer. Such noise can be due to a number of sources which must be eliminated or their effects guarded against, since those non-signal noise spikes can trigger the threshold detector and appear as signals on the other indicators. Common sources of external noise are fluorescent lighting, high voltage discharge and especially, less than optimum installation and support of the transducer cabling.

The latter source normally may be eliminated by redressing the cable, tightening or cleaning the connector at the transducer, or even replacing the transducer or transducer cable. To verify that no extraneous noise exists in the system, observe the oscilloscope while turning on the shaker and increasing the drive amplitude from zero to the desired acceleration level (see 3.1 c.) while applying the co-shock (see 3.3.4). This noise is usually present as pulses which remain in a fixed position on the oscilloscope trace. If extraneous noise is observed, correct the problem by shielding or other precautions, such as those suggested above and re-run the entire noise check.

3.3 Test sequence.

a. Pre-test shock.
b. Vibration 3-5 seconds.
c. Co-test shock.
d. Vibration 3-5 seconds.
e. Co-test shock.
f. Vibration 3-5 seconds.
g. Co-test shock.
h. Vibration 3-5 seconds.
i. Accept or reject.

3.3.1 Pre-test shock. Prior to vibrating the device, it shall receive a pre-test shock of 500 to 1500g (see 2.1).

3.3.2 Mounting requirements. Special precautions (e.g., in mounting, grounding of DUT leads, or grounding of test operator) shall be taken as necessary to prevent electrostatic damage to the DUT. All devices shall be mounted in an inverted position without adapters except for the following:

a. Stud-mounted devices shall be mounted in suitable adapters.
b. Axial diodes shall be mounted without adapters and with the leads in a horizontal plane.
c. Double-ended resistance welded packages (i.e., optical isolator) shall be mounted using a suitable adapter and with the leads horizontal. Most part types will mount directly to the transducer via the attachment medium. Parts shall be mounted with the largest flat surface against the transducer at the center or axis of the transducer for maximum sensitivity. When so mounted, the leads of the part will point up (e.g., TO-5) or horizontal (e.g., flat packs). Where more than one large surface exists, the one that is the thinnest in section or has the most uniform thickness shall be mounted toward the transducer, e.g., flat packs are mounted top down against the transducer. Small axial-lead, right circular cylindrical parts are mounted with their axis horizontal and the side of the cylinder against the transducer. Parts with unusual shapes may require special fixtures. Such fixtures shall have the following properties:

1. Low mass.
2. High acoustic transmission (aluminum alloy 7075 works well).
3. Full transducer surface contact, especially at the center.
4. Maximum practical surface contact with test part.
5. No moving parts.
6. Suitable for attachment medium mounting.

Leads on the parts shall be dressed, as necessary, so they will not strike each other or the transducer during vibration. Long or thin section leads shall be observed for signs of resonance, indicated by motion exceeding 3 or 4 diameters. Such resonance may give extraneous noise during test even though the leads do not strike each other. In these cases, the leads may have to be shortened (if permitted by the application) or special fixturing or frequency changes may be required.

NOTE: Some especially long-leaded TO-5 packages have been observed to be close to resonance at the test frequency.

3.3.3 Test monitoring. To avoid false indications, the DUT shall be inspected for any attached foreign matter or leads which are touching each other. The DUT shall be mounted on the center of the transducer using attachment medium and if

necessary, a mounting adapter. To provide maximum signal transmissibility with a viscous couplant, a sufficient amount of couplant shall be used and the DUT shall be firmly mounted so that any excess couplant can be squeezed out. When double-faced tape is used, it shall be changed at the start of a test group and after each 25 units or less thereafter. Devices shall be put on and removed from the attachment medium with a slight twisting motion. Device orientation for each package type shall be as specified in 3.3.2. The shaker input frequency shall be set in accordance with 3.1 b. and the shaker drive amplitude shall be increased to the level specified in 3.1 c All detection systems shall be monitored for evidence of loose particles. Any device which gives a particle indication shall be considered a reject. Particle indications can occur in any one or combinations of the three detection systems as follows:

a. Visual indication of high frequency spikes which exceed the normal constant background white noise level.
b. Audio indication of clicks, pops, or rattling which is different from the constant background noise present with no DUT on the transducer.
c. Threshold detection shall be indicated by the lighting of a lamp or by deflection of the secondary oscilloscope trace.
d. If no particles are observed in 3 to 5 seconds, a co-test shock (see 3.3.4) shall be applied to the DUT while the shaker is operating. It is permissible to interrupt or perturb the vibration for a period not to exceed 250 milliseconds to provide for the application of an integral co-test shock. The audio, oscilloscope, and threshold detection systems are to be closely monitored during the time period immediately after each shock application as well as for an additional 3 - 5 seconds to detect particles which may lock up quickly. If no particles are detected with the first co-test shock application, the test shall be repeated two times. If there is no indication of particles within 5 seconds after the third co-test shock (see 3.3.4), the device is acceptable.

3.3.4 Co-test shock application. When using the copper rod shock tool (see 2.i.), the shock shall be applied to the DUT by bringing at least 1/4 to 1/2 inch of the free end of the shock tool into momentary contact with the vibrating DUT. The tool shall be held lightly and freely between the thumb and forefinger opposite the free end. Striking or hammering motions shall not be used. The shock shall be only the result of the mass inertia of the freely supported shock tool being struck by the vibrating DUT. The tool shall be held approximately horizontal and shall contact the DUT on a portion of the upper surface of its case. The duration of this contact is on the order of one-half second and results in several impacts of random shock to the DUT. The tool shall not contact the leads, other than minor accidental brushing of the leads along and parallel to their axis and shall not contact any glass portion of the case, except for all glass envelope diodes. If any other co-test shock device is used, its mode of operation shall be in accordance with procedures supplied by the equipment manufacturer. In systems that disable the threshold detector during the co-test shock, the period of time from shock pulse to reinitiation of threshold detection shall not exceed 100 milliseconds.

3.4 Failure criteria. Any noise bursts as detected by any of the three detection systems exclusive of background noise, except those caused by the shock blows, during the monitoring periods shall be cause for rejection of the device. Rejects shall not be retested (see 3.3.3) except for retest of all devices in the event of test system failure as provided in 3. If additional cycles of testing on a lot are specified, the entire test procedure (equipment set-up and checkout mounting, vibration, and co-shocking) shall be repeated for each retest cycle. Reject devices from each test cycle shall be removed from the lot and shall not be retested in subsequent lot testing.

4. SUMMARY. The following details shall be specified in the applicable detail specification:

a. Test condition letter A or B (see 2.d. and 3.1 c.).
b. Lot acceptance/rejection criteria (if applicable).
c. The number of test cycles, if other than one.
d. Attachment medium, if other than that specified (see 2.h.).
e. Pre-test shock level and co-test shock level, if other than specified in 2.1. and 2.i., respectively.

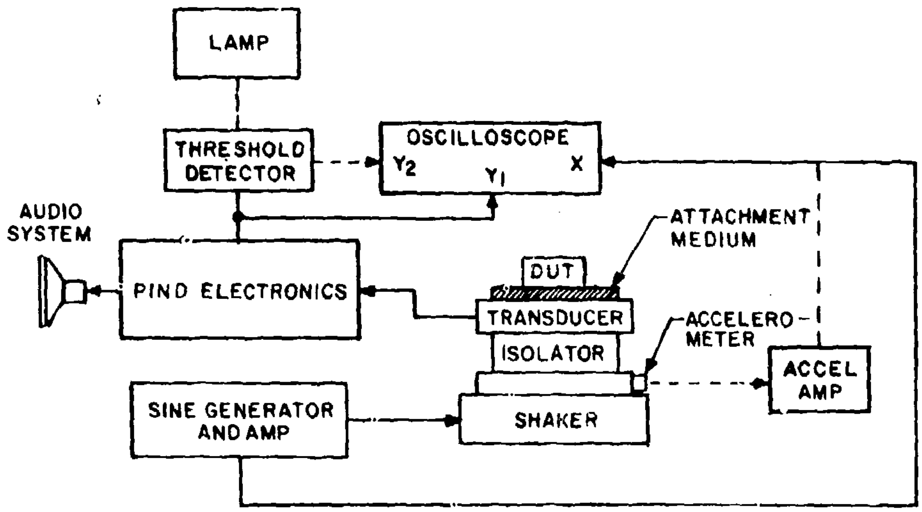


FIGURE 2020-1. Typical particle impact noise detection system.

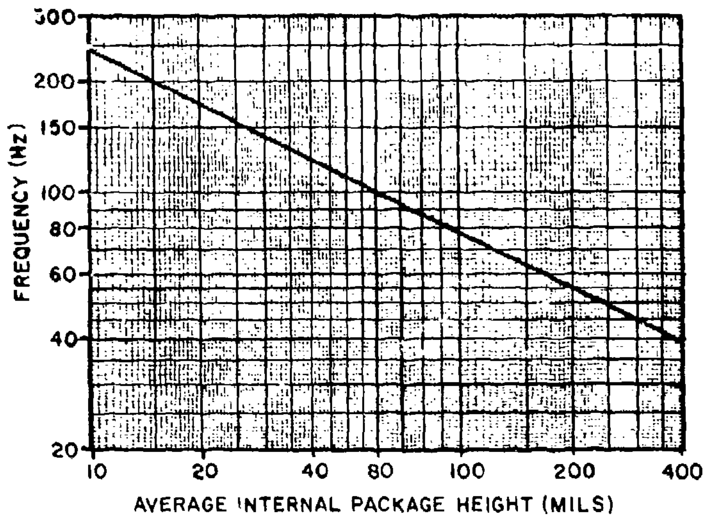
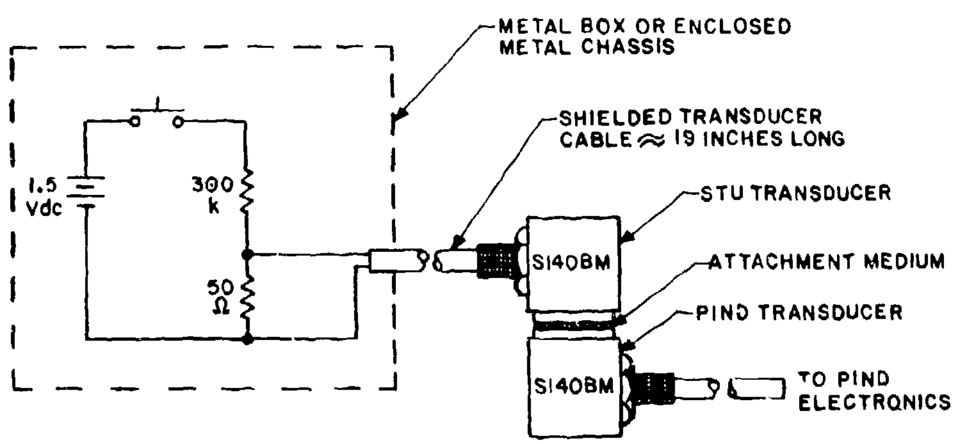
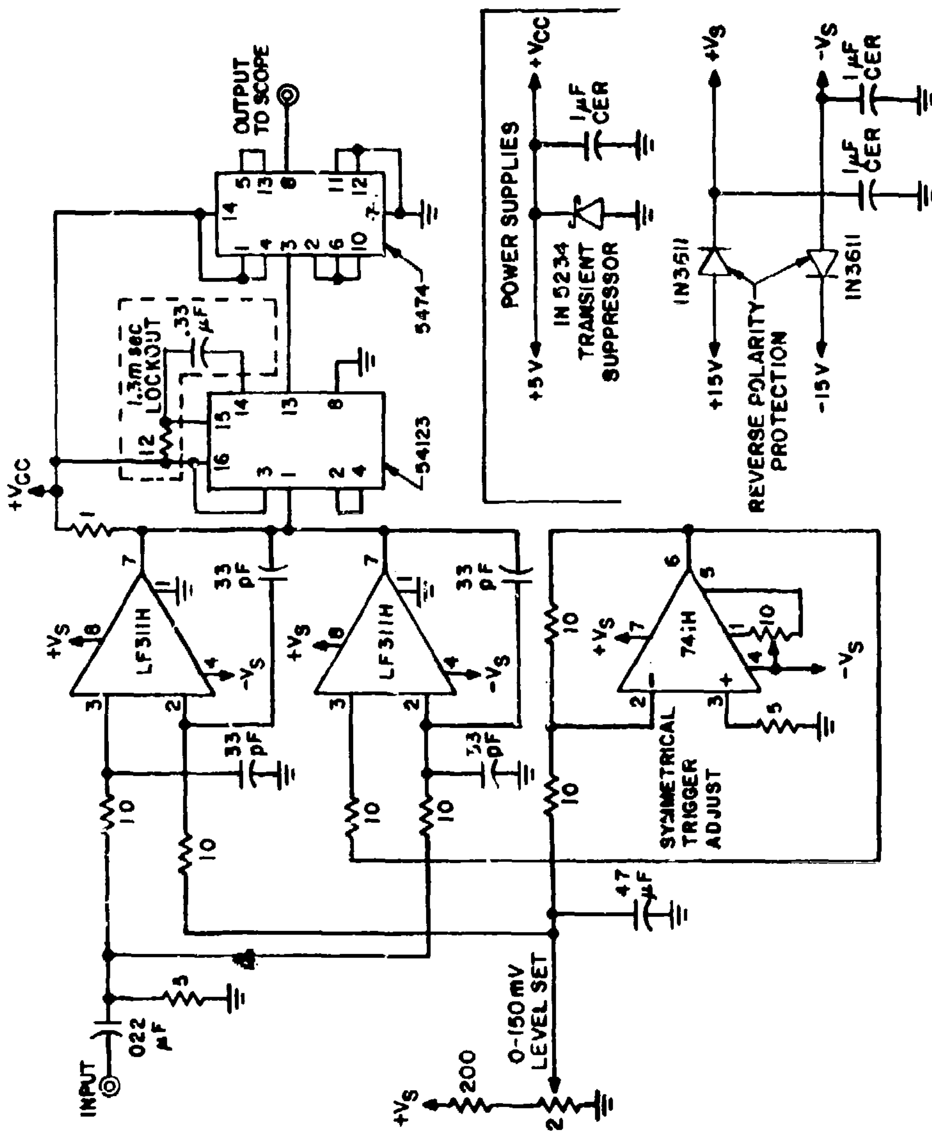


FIGURE 2020-2. Package height vs test frequency for 20G accleration (condition A).



NOTES:
1. Pushbutton switch: Mechanically quiet, fast make, gold contacts. E.G. T2 SM4 microswitch.
2. Resistance tolerance 5% non-inductive.
3. Voltage source can be a standard dry cell.
4. The coupled transducers must be coaxial during test.
5. Voltage output to STU transducer 250 microvolts, ±20%.

FIGURE 2020-3. Typical sensitivity test unit.



Resistance values are in kilo⁻⁻ unless otherwise specified.

FIGURE 2020-4. Typical threshold detector schematic.

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